STATIC AIR MIXING APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part and claims priority from U.S. Application Serial No. 10/189,705 filed on July 3, 2002 entitled "Static Air Mixing Apparatus."

TECHNICAL FIELD

This invention relates to heating, ventilating and air conditioning systems, and more particularly, to an air mixing apparatus of simplified construction which still achieves adequate mixing efficiency while maintaining a uniform velocity profile and minimum pressure drop.

BACKGROUND OF THE INVENTION

Air streams which are introduced at different temperature levels through a common duct in heating, ventilating and air conditioning (HVAC) systems require intimate mixing in the duct in order to avoid undesirable stratification of air prior to passage of the airstream into a room airspace to be heated or cooled. Failure to achieve intimate mixing in the duct ultimately results in inefficient heating and cooling of the room air space and therefore can significantly affect the cost in operating and maintaining an HVAC system.

A number of prior art references exist which disclose various static air mixing devices. The assignee of the current invention is the owner of a number of previous patents to include U.S. Patent Nos. 3,180,245; 4,495,858; 5,645,481; and 5,536,207. Each of these references are hereby incorporated by reference for teaching the basic air mixing apparatuses disclosed therein.

An air mixing device installed in an air duct inherently creates a pressure drop in the airflow across the air mixer during operation. This pressure drop is undesirable and therefore, efforts to minimize pressure drop is a main consideration in static air mixing design. Of course, it is also desirable to maximize the efficiency of the mixing that takes place immediately downstream of the mixing apparatus as well as to maintain a uniform velocity profile downstream of the mixing device.

Earlier mixer designs typically had mixing efficiencies of around 30%. In later mixer designs, mixing effectiveness has been greatly improved, and it is not uncommon to find mixers with efficiencies of around 50 or 60%. With the optimized construction of the air mixers disclosed in the U.S. Patent Nos. 5,645,481 and 5,536,207, air mixing effectiveness of at least 65% was achieved.

Although mixing efficiency has improved due to newer mixer designs, one drawback from some of the newer mixer designs is the complexity of the air mixers, and the cost to manufacture such units.

Therefore, there is a need for development of yet a different mixer design which still achieves acceptable mixer effectiveness, but is of a simpler design which reduces manufacturing costs and makes the mixer more available for all types of commercial use.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved static air mixing apparatus which still achieves acceptable mixing effectiveness; however, the design of the mixer is simplified to reduce manufacturing costs.

Other objects of the invention include, but are not limited to, providing a static air mixing apparatus which still maintains a minimum pressure drop, yet is able to maintain a uniform downstream velocity profile.

In accordance with the present invention, a static air mixing apparatus is provided which meets the aforementioned needs. As with the previous static air mixing apparatuses of the assignee, the current static air mixing apparatus is installed within a duct wherein an enclosure partially traverses the duct defining a core area therein. A plurality of radially extending curved vanes are centered within the enclosure, and the vanes diverge away from a center of the enclosure and terminate at their outer distal ends at or adjacent to the inner wall of the enclosure. The vanes can be defined as including an inner section wherein the vane curves downstream in a first direction, and an outer section which lies radially outward from the inner section; however, the outer section curves downstream in a second direction away from the first section. An interface can be defined as the location at which the distal end of the inner section abuts the proximal end of the outer section. At this interface, the vane is split into its oppositely arranged curved sections.

It is also contemplated within the current invention that yet another section of the vane can be provided which is curved in yet a third direction downstream, similar to the first direction of the inner section.

Although each vane has been defined as having an inner and outer section, the invention can also be thought of as including a plurality of inner vanes and outer vanes wherein an inner vane and a corresponding outer vane share a common leading edge, but have divergent trailing edges.

In the second embodiment of the present invention, a static air mixing apparatus is provided by a plurality of flaps and vanes which are formed from a single sheet of material and placed transversely within a duct, the flaps and vanes being provided in patterns which create mixing of air. Each vane and flap remains attached to the sheet by a leading edge that is not cut or separated from the sheet.. While mixing effectiveness may be somewhat sacrificed, the particular design of the second embodiment is even simpler than that of the first embodiment. The vanes in the second embodiment are centered within the enclosure, extend radially away from a center of the enclosure, and terminate at a desired radial distance from the center. The vanes each have a leading edge at the transversely mounted sheet, and a trailing edge which extends downstream at a particular desired angle. This angle can vary anywhere in the range from approximately 30° to 90°, the angle being measured downstream from the sheet extending transversely across the duct. At 90°, there is little or no mixing that occurs. As the vanes are bent towards a smaller angle, mixing is increased as well as pressure drop across the device. Surrounding the group of vanes is an outer group of flaps or panels which are also formed from the same sheet of transversely mounted material forming the mixing apparatus. With a four-sided duct, the most preferred arrangement is to include two flaps per side of the enclosure, thereby providing a total of eight flaps which surround the inner set of vanes. The flaps are also bent to a downstream angle between about 30° to 90°, depending upon how much mixing is desired. Although the simplest arrangement for this second embodiment is to provide features that extend straight downstream, it may be desirable to also provide a downstream curvature to the inner set of vanes, similar to the first embodiment.

In comparison to the apparatuses disclosed in U.S. Patent Nos. 5,645,481 and 5,136,207, the air mixer of the present invention has slightly less mixing efficiency; however, the construction of the present invention is greatly simplified which reduces manufacturing costs. Furthermore, the mixing method of the present invention greatly differs from the previous inventions of the assignee as further explained below. A comparison of the turbulence created by the present mixer design clearly shows the structural differences in the present invention also results in different air mixing dynamics.

The above and other objects of the present invention will become more readily appreciated and understood from a consideration of the following detailed description of the preferred form of the present invention when taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of the air mixing apparatus of the present invention which is installed within a duct, relevant portions of the duct walls being broken away in order to fully view the air mixing apparatus, and Figure 1 being a rear view of the air mixing apparatus taken downstream of the air mixing apparatus;

Figure 2 is a perspective view of the air mixing apparatus taken upstream of the air mixing apparatus, and removed from the duct;

Figure 3 is a perspective view of a duct having a rectangular cross section with portions broken away to reveal a series of three air mixers disposed in a side by side relation,

thus illustrating one arrangement in which more than one air mixing apparatus of the present invention can be enclosed within a duct of a particular size or shape;

Figure 4 is a greatly enlarged fragmentary perspective view of the hub of the air mixing apparatus, illustrating how the vanes of the air mixing apparatus attach to the hub;

Figure 5 is a cross sectional view of one of the vanes taken along line 5-5 of Figure 1 specifically illustrating the interface or junction between the inner and outer sections of the vane which diverge away from one another in the downstream direction;

Figure 6 illustrates a plan view of a vane prior to being cut and bent in final form, the vane being constructed from a single piece of material, and the Figure also showing incorporation of a clip angle;

Figure 7 is a rear elevation view of the air mixing apparatus of the present invention, specifically illustrating the various vortices which are created downstream of the air mixing apparatus as airstreams pass through the air mixing apparatus; and

Figure 8 is a perspective view of a modification to the air mixing apparatus of the present invention, and Figure 8 further being a rear view of the air mixing apparatus as taken downstream of the air mixing apparatus;

Figure 9 is a rear elevation view of the air mixing apparatus shown in Figure 8, specifically illustrating the various vortices which are created downstream of the air mixing apparatus as air streams are passed through the air mixing apparatus;

Figure 10 is a plan view illustrating another configuration for a vane wherein the width of the outer section extends beyond the width of the inner section, and the outer section also includes a clip angle;

Figure 11 is a rear elevation view of the modification to the air mixing apparatus incorporating the construction of the vane shown in Figure 10;

Figure 12 is another plan view of a vane construction similar to Figure 10; however, the vane does not incorporate a clip angle at the outer section;

Figure 13 is a rear elevation view of the modification to the air mixing apparatus incorporating the construction of the vane shown in Figure 12;

Figure 14 is another perspective view of the air mixing apparatus of the present invention in an additional embodiment, shown installed within a duct, with relevant portions of the duct walls being broken away in order to fully view the air mixing apparatus; and Figure 10 further being a rear view of the apparatus taken downstream; and

Figure 15 is a rear elevation view of the air mixing apparatuses shown in U.S. Patent Nos. 4,495,858; 5,645,481; and 5,336,207, and specifically illustrating the vortices which are created by the air mixing apparatuses of those inventions.

DETAILED DESCRIPTION

Figures 1 and 2 illustrate the static air mixing apparatus of the current invention, shown as mixing apparatus 10. The apparatus includes an enclosure 14 which is mounted within and partially traverses a duct 12. The air mixing apparatus 10 is a static device which has no moving parts. Preferably, the enclosure 14 has an octagonal shape including eight corresponding rectangular panel portions joined in an end-to-end relation to one another. The enclosure 14 carries a plurality of radially extending vanes or blades 16 which diverge away from a center of the enclosure, and terminate at their outer distal ends at the inner wall

surface 17 of the enclosure 14. Preferably, the vanes 16 are uniformly spaced from one another, and each of the vanes includes an inner section 18 and a corresponding outer section 20 which shares a common leading edge with the inner section 18. The inner sections 18 of the vanes are preferably curved in the same downstream direction to impart either a clockwise or counterclockwise rotation to air passing through the mixing apparatus 10. Similarly, the outer sections 20 of the vane also are curved, but at a different angle in the downstream direction to impart either a clockwise or counterclockwise rotation to air passing therethrough. As further discussed below, the particular vane arrangement shown in Figures 1 and 2 provide a particular vortices pattern resulting in efficient mixing of airstreams, yet the design of the present mixer is simplified to reduce manufacturing costs.

Although each of the vanes shown in Figure 1 have an inner and outer section, it is contemplated within the spirit and scope of this invention that the vanes having an inner and outer section could be dispersed among inner vanes of the type shown in the assignees previous inventions. Thus, a composite pattern of vanes could be provided.

In order to provide a flow of the airstreams through the air mixing apparatus, power is supplied by an upstream fan system or downstream fan system (not shown). The vanes 16 within the enclosure 14 are preferably joined together at a central hub 22. Alternatively, the vanes may be spot welded together at the center of the enclosure, or they may be entirely cantilever supported from the inner wall surfaces 17 of the enclosure 14.

The enclosure 14 is supported in the duct 12 by a support plate 24 transversely mounted in the duct 12 so that all air passing through the duct 12 must pass through the air mixing apparatus 10.

Figure 2 illustrates the air mixing apparatus removed from the duct. As shown in Figures 1 and 2, the enclosure 14 comprises the octagonally arranged panels which may be made from a flat strip of rectangular sheet material, such as sheet metal used in air conditioning duct work folded to create the eight-sided arrangement. As understood by those skilled in the art, the octagonal enclosure could also be made of other acceptable material to include other types of sheet stock. Furthermore, it should be understood that the shape of the enclosure 14 could be hexagonal, circular, or any other polygonal shape which surrounds the plurality of vanes.

The inner sections 18 of the vanes extend radially outward in a straight line towards the enclosure 14 from the central hub 22 positioned at the center of the enclosure. In the embodiment shown in Figures 1 and 2, eight vanes are provided; however, it shall be understood that the number of vanes can also be modified to provide the desired air mixing result. As further discussed below with respect to Figure 6, the inner sections 18 include a leading edge 26, a trailing edge 28, and a curved portion 29 interconnecting the leading and trailing edges. The proximal or inner end of outer section 20 is shown as proximal end 42. Similarly, the outer sections 20 include the common leading edge 26, a trailing edge 33, and a curved portion 35 interconnecting the leading and trailing edges. The distal or most outer end of inner section 18 is defined by distal end 40.

Figure 3 illustrates one manner in which a plurality of air mixing apparatuses 10 may be arranged within a particular shape and sized air duct 12. As shown, three air mixing apparatuses 10 are disposed adjacent to one another within a rectangular shaped duct 12. It will be appreciated that the air mixing apparatuses of the invention can be arranged in other

side-by-side arrangements to fit the particular shape of a duct in which mixing of airstreams is desired.

Figure 4 illustrates one preferred way in which the vanes 16 may be attached at the central hub 22. As shown, the central hub 22 may include a rod 30 which interconnects a hub tab 31 and a slotted connector plate 32. The connector plate 32 includes a plurality of spaced slots 34, there being one slot each for a corresponding vane to be inserted therein. Accordingly, the most proximal or inner ends 46 of the vanes 18 are inserted within the corresponding slots 34.

Figure 5 illustrates a cross-section of a vane 18 taken along line 5-5 of Figure 1, and the preferred angles at which the inner and outer sections diverge from one another. As measured from a center of curvature for the inner section 18, the curvature of the inner section further being defined as having a radius R_1, the preferred downstream angle or pitch for the inner section 18 is an angle of approximately 65°. For the outer section 20, a preferred angle of downstream curvature would be in the range of 65° to 90°, the curvature also being measured from a center point of curvature for the outer section, and having a radius shown as R_2. Although 65° and a range of 65° to 90° have been provided as preferable downstream pitch angles for the respective inner and outer sections, it shall be understood that the invention is not limited to the pitch angles and these angles can be modified to provide the desired downstream turbulence for mixing of the airstreams.

Figure 6 illustrates how a vane 16 of the present invention can be cut from a singular rectangular piece of material. As shown, the inner section 18 is shaped by removal of a triangular portion of the material (shown in dotted lines) located at the proximal end 46. The

angle at which the material is removed constitutes the clip angle, denoted by the angle subtended by arc 38. As discussed with respect to the previous patents of the assignee, the clip angle or relieved area thus constitutes a portion of the inner section of the blade having an inclined surface 36. The preferred method for determining a preferred clip angle is set forth by the following equation:

Preferred clip angle = 90-360/number of blades

Thus, for the preferred embodiment shown in the Figures, the clip angle would be:

Preferred clip angle = 90-360/8

= 45°.

Although a preferred method is set forth for determining a desirable clip angle, the invention herein shall not be interpreted as being limited to such a clip angle. Furthermore, the method sets forth a desirable approximation for the clip angle and small deviations to the calculation within a few degrees would still substantially confirm to an acceptable range.

In order to form the outer section 20 of the blade, the material can be cut along the dotted line denoted by line 40/42, the cut extending toward the connection point 44 between the inner and outer sections. Then, the desired curvature or pitch of the respective inner and outer sections can be provided by bending the inner and outer sections away from one another.

Figure 7 is a rear elevation view of the air mixing apparatus of the present invention, viewing the air mixing apparatus from a downstream location. The directional arrows in Figure 7 denote the various vortices which are created by the pattern of the vanes. As discussed above, it is desirable to create downstream turbulence from the air mixing

apparatus in order to adequately intermix the airstreams. The vortices are the discrete patterns of air which are created in the airstreams as they pass through the air mixing apparatus. The vortices have circulation patterns of greater velocity as they exist closer to the air mixing apparatus., As the airstreams move downstream, the vortices patterns become more divergent and have slower velocities.

As shown in Figure 7, the vortices patterns created include a central vortex 60 which primarily circulates in a counterclockwise and downstream direction. Each of the blades create a smaller clip angle vortex 62 which is located near the distal end of the inclined edge 36. As shown, these clip angle vortices 62 also generally circulate in a counterclockwise and downstream direction. Another set of vortices are created at the interface between the inner and outer sections. This group of vortices is shown as interface vortices 64. These vortices generally circulate in a clockwise and downstream direction, and the size of these vortices are generally larger than the vortices 62. Finally, an outer vortex 66 is created, the outer vortex circulating in a clockwise and downstream direction. Thus, from viewing the air mixing apparatus 10 from its center to the enclosure 14, there are four vortices patterns which are encountered, and which result in efficient mixing of the airstreams.

Figure 8 illustrates a modification to the embodiment of Figure 1 wherein a static air mixing apparatus 10′ further includes an additional outer portion 21. This additional or outer most portion 21 also shares a common leading edge with inner section 18 and outer section 20, and most outer portion 21 has a curvature which matches that of inner section 18. By incorporation of most outer portion 21, additional vortices are created thereby producing a different mixing pattern.

Referring to Figure 9, the particular vortex patterns created are illustrated. The pattern in Figure 9 includes the central vortex 60, the clip angle vortices 62, the interface vortices 64, as well as two additional sets of vortices. These additional vortices are illustrated as outermost interface vortices 90 which are formed at the interface between outer section 20 and most outer portion 21, and duct interface vortices 92 which are formed at the interface or junction of the most outer portions 21 and the walls of the enclosure 14. From this modification shown in Figures 8 and 9, it can be seen that different vortices patterns may be created, and which therefore can be modified to effect the desired mixing.

Figure 10 illustrates another configuration for the vanes. In this configuration, the effective width of both the inner section 18' and the outer section 20' has been increased to close the gap or open space surrounding the outer section when installed. Additionally, the outer section 20' has a width that is greater than the width for the inner section 18'. This increased width is defined by the extension 86 that extends beyond the trailing edge 28. Furthermore, each outer section 20' may also have its own clip angle which can be designed in accordance with the description of the clip angle set forth above. The clip angle here is defined by the inclined surface 88. By increasing the size of the outer sections, pressure drop will increase across the mixing device, in comparison to the vane configuration of Figure 6, since airstream flow will be limited to a smaller open area; however, mixing efficiency will increase.

Figure 11 illustrates a mixer incorporating the vane configuration of Figure 10.

Figure 12 illustrates another vane configuration that is the same as that shown in Figure 10, with the exception that no clip angle is provided at the outer section 20'.

Accordingly, even greater pressure drop will be experienced because additional surface area is added to the overall vane pattern thereby inhibiting airstream flow. Use of a vane configuration as shown in Figure 12 also results in greater overall mixer efficiency in comparison to the vane configuration of Figure 6.

Figure 13 illustrates a mixer incorporating the vane configuration of Figure 12.

The second embodiment of the invention is shown in Figure 14 The air mixing apparatus 100 shown there is a further simplified design wherein a transversely mounted sheet of material 104 is placed across a duct 102. The sheet 104 may have a combination of inner vanes 106 and outer flaps 108. In the particular pattern shown, there are four inner vanes 106 and eight outer flaps 108. The four inner vanes 106 are created by simply cutting out rectangular shaped sections from the sheet 104, and maintaining one side edge attached to the sheet. Optionally, a triangular shaped section may be then cut from each of the vanes 106 to create a desired clip angle. The clip angle or relieved area thus constitutes a portion of the vane having an inclined surface 109. A particular clip angle may be provided as discussed above with respect to the first embodiment. A central hub 107 will remain at the intersection of the inner vanes. As necessary, structural support may be incorporated between the inner vanes 106 by a crossing pattern of sheet metal which abuts the leading edges of the vanes. The sheet metal supports could simply be cut to strips which traverse across the duct and thereby stabilize the vanes 106. As for the outer flaps 108, they may be constructed by cutting out rectangular shaped sections that also have one edge remaining attached to the plate 104. The inner vanes 106 and outer flaps 108 are illustrated without curvatures. It is also contemplated that both the vanes and the flaps can be bent to a desired

curvature in order to create desired vortex patterns. Of course, simply cutting out the vanes and flaps and bending them a desired angle with respect to the plate 104 is the most simple way in which to effect mixing.

Referring now to Figure 15, a comparison of the air mixing apparatus 10 of the present invention versus the air mixing apparatus 70 of the assignee's earlier inventions shows that the present invention is structurally simplified, yet still provides adequate air mixing. As disclosed in assignees earlier inventions, the structure of the air mixing apparatuses include an outer enclosure 71, an inner enclosure 72, a plurality of radially extending inner vanes 74, and a plurality of outer vanes 76 which are disposed between the inner and outer enclosures. Unlike the present invention, each of the outer vanes 76 are separated vane structures which are not connected to any corresponding inner vanes 74. Furthermore, the air mixture 70 includes an additional enclosure, namely the inner enclosure 72.

The vortices patterns created in the air mixing apparatus 70 includes a central vortex 78 and a plurality of clip angle vortices 80. Thus, both the present mixer design and the air mixing apparatus 70 both include similar central vortices and the plurality of clip angle vortices. However, the vortices patterns created radially outward of the clip angle vortices 80 in the air mixing apparatus 70 substantially differ from the vortices patterns created in the present mixer design. As shown, the air mixing apparatus 70 includes an intermediate vortex 82 which rotates in a counterclockwise and downstream direction, and an outer vortex 84 is created between the inner and outer enclosures, the outer vortex 84 circulating in a clockwise

and downstream circulation pattern. Thus, the air mixing apparatus 70 has no interface vortices 64 like the present invention.

In the first embodiment, because of the increased gap between the outer sections 20 in comparison to the gaps between the outer vanes 76 of the previous air mixer design, there is more airstream flow through the outer portions of the mixer. Additionally, since there is no inner enclosure in the present mixer design, removal of this partition or enclosure allows more flow of air from the outer portion of the mixer to the inner portion of the mixer. This increased airflow through the present mixer design reduces the amount of shear present in the airstream flows, and thus accounts not only for the lower pressure drop across the present mixer design, but also the incremental loss in efficiency. It has been found through testing that the mixer design of the first embodiment has approximately 80% of the pressure drop in comparison with the previous mixer design, and the effectiveness of the first embodiment mixer design is approximately 10% less than the previous mixer design. However in a comparison of the construction between the present mixer design and the apparatus shown as mixture 70, the present mixer design is substantially simpler, thus greatly reducing manufacturing and assembly costs. Of particular note is the decreased number of parts and required welds to assemble the mixer of the first embodiment. For the first embodiment, the only required welds or connections are those located at the distal ends of the outer sections 20 which connect to the inner wall surfaces 17. For the second embodiment, no welds are required because each of the vanes and flaps are simply formed as cutouts from a single sheet stock. As mentioned above, in order to increase mixer efficiency for the first embodiment,

the gaps between inner sections of the vanes can be decreased and/or the size and shape of the outer sections may be modified.

While the present invention has been described in its application to mixing of airstreams of different temperature, the present invention is conformable for use in virtually any application for mixing fluid streams to include air or gaseous streams, or even liquid streams. The fluid streams can be either composed of similar or dissimilar fluid components or concentrations of the components. Thus, the present invention has a wide range of applications.

It is therefore to be understood that while preferred forms of the invention have been set forth and described herein, various modifications and changes will become apparent to those skilled in the art without departing from the spirit and scope of the present invention as defined by the appended claims.